Projected climate change impacts of the European wild mammal species' habitats using RCM simulations

Theses of the PhD dissertation

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1. Investigated problems, aims

Changing climate affects not only humans and therefore the urban environment, but also the living conditions of wild animals. Animals tend to occupy geographical regions with climatic conditions, which are optimal to their specific needs. Due to the projected climate change the living territory of wild animals' may be reshaped in the future, some of the species may even suffer extinction.

The aim of my doctoral research was to make a comparative study for the 21st century predictions of the European wild mammals' vulnerability to the climate change, by using the model simulation result. Climate is one of the abiotic factors, which controls primarily the range areas of wildlife; therefore we have determined the most endangered wild European mammals for the entire 21st century, considering species richness estimations for regions. For this purpose the result were presented through four examples: common pipistrelle (*Pipistrellus pipistrellus*), European mole (*Talpa europaea*), European brown hare (*Lepus europeaus*), elk (*Alces alces*), and three case studies of all European: bat species (*Microchiroptera*), mole species (*Talpidae*), rabbits and hare species (*Leporidae*).

Global warming implies increasing temperature, dryer summers and wetter winters in the Carpathian Basin; therefore we have analyzed the possible regional impacts to the living territory and conditions of wild terrestrial mammals in Hungary. Furthermore we have determined the most endangered wild terrestrial mammal species in the analyzed region for the entire 21st century.

Finding widely referenced available datasets and appropriate methodology were the basis of these analyses. The results presented in the thesis can be useful for the adaptation to the expected regional impacts of climate change and development of strategy.

2. Applied datasets, methodology

In the presented studies, simultaneous analysis of the current range maps from The Atlas of European Mammals and the E-OBS observations database for 1961-1990 and bias-corrected outputs of the RACMO simulation were used to determine the climatically optimal areas of all studied mammal species in Europe. For the simultaneous analysis of the various datasets, first the distribution data from the atlas was digitalized than converted from the original 50 km to 25 km resolution.

Species climate indicator profile technique was used to determine the climatically suitable areas of all studied mammals. To characterize the climate indicators of all mammal species, we used the 30 year averages of the four climatic parameters (daily mean temperature, daily minimum temperature, daily maximum temperature and daily precipitation sum), based on the gridded E-OBS dataset for 1961-1990. Then, we estimated the optimal climatic requirements, which intervals are mapped for the past (1961-1990), and for the future time periods of 2021-2050, 2071-2100, using RACMO simulated data, considering SRES A1B scenario with 25 km horizontal resolution.

The graphs of the index Q's values related to the four climate parameters were presented using Gnuplot command-driven interactive function plotting program. Than the individual maps of the climatic indicators intervals were presented on maps for the past (1961-1990) and also for the middle (2021-2050) and the end (2071-2100) of the 21st century. Than the climatically suitable area of the four climatic parameters (daily mean temperature, daily minimum temperature, daily maximum temperature, daily precipitation sum) were presented on maps and composite maps for the recent past (1961-1990), and also for the middle (2021-2050) and the end (2071-2100) of the 21st century based on the model simulations, using GrADS display software.

Comparing these composite maps to the original distribution maps, we analyzed the expected changes in spatial status and size of the studied species' climatically suitable areas in the future. Conclusions can be drawn from the differences between studied regions, as well as changes in species diversity. In addition, spatial analogy technique was used to analyze the in the expected changes of the studied wild mammals' habitats in the Carpathian Basin, which were presented in tables and graphs.

Potential changes in spatial status and size of the studied species' habitat were quantified, and presented on tables.

3. Results and conclusions

1. According to the species' climate profile technique, northward shift of all studied 112 mammals' climatically suitable areas is expected, based on the model simulations.

2. The results suggest that, climatically suitable area of 13 wild mammal species out of the studied 112 may disappear by 2021-2050. 2 out of the above mentioned 13 species' area may reappear by 2071-2100, and the other 11 species' climatically suitable areas are projected to disappear until the end of the 21st century.

3. Including all four studied European regions, the results suggest decline in species richness occur in Northwestern Europe, Temperate Europe and Southern Europe regions by the mid-century, except Northern Europe, where will be a stagnating trend.

4. Including all four studied European regions, the results suggest that the greatest decline in species richness occur in Northwestern Europe and Southern Europe. In these European regions only 65 and 82 species' climatically suitable area will occur by 2021-2050, compared to the determined 72 and 89 species in the reference period of 1961-1990.

5. Including all four studied European regions, the results suggest that the greatest decline in species richness occur in Northwestern Europe with only 45 species' climatically suitable area will occur by 2071-2100, compared to the determined 72 species in the reference period of 1961-1990.

6. Including all four studied European regions, the results suggest that the greatest increase in species richness occur in Northern Europe with only 72 species' climatically suitable area will occur by 2071-2100, compared to the determined 37 species in the reference period of 1961-1990.

7. According to the results for the Common pipistrelle (*Pipistrellus pipistrellus*), the species' climatically suitable area is expected to shift northward by 2071-2100. In addition, the species' climatically suitable area may decrease from 1,498,350 km^2 to 1,154,040 km^2 until 2021-2050 and to 948,767 km^2 by 2071-2100, which means a 23% and 37% area decline, compared to the observed time period of 1961-1990.

8. From the studied 28 bat species (*Microchiroptera*), Mehely's horseshoe bat's (*Rhinolophus mehelyi*) optimal climatic conditions are projected to disappear by 2071-2100.

9. According to the results for the European mole (*Talpa europaea*), the species' climatically suitable area is expected to shift northward by 2071-2100. In addition, the species' climatically suitable area may decrease from 1,334,300 km^2 to 1,089,380 km^2 until 2021-2050 and to 1,111,230 km^2 by 2071-2100, which means a 18% and 17% area decline, compared to the observed time period of 1961-1990.

10. From the studied 3 mole (*Talpidae*) species, Roman mole's (*Talpa romana*) optimal climatic conditions are projected to disappear by 2021-2050.

11. According to the results for the European brown hare (*Lepus europaeus*), the species' climatically suitable area is expected to shift northward by 2071-2100. In addition, the species' climatically suitable area may decrease from 1,701,200 km^2 to 1,504,200 km^2 until 2021-2050 and to 1,561,960 km^2 by 2071-2100, which means a 12% and 8% area decline, compared to the observed time period of 1961-1990.

12. From the studied 5 rabbit and hare (*Leporidae*) species, Cape hare's (*Lepus capensis*) optimal climatic conditions are projected to disappear by 2021-2050.

13. According to the results for the elk (*Alces alces*), the species' climatically suitable area is expected to shift northward by 2071-2100. In addition, the species' climatically suitable area may decrease from 1,154,890 km^2 to 948,733km^2 until 2021-2050 and to 518,404 km^2 by 2071-2100, which means a 18% and 55% area decline, compared to the observed time period of 1961-1990.

14. According to the results based on the climate analogue technique suggest that from the reference period of 1961-1990 among the studied mammal species, the Eurasian beaver (*Castor fiber*), pond bat (*Myotis dasycneme*), western barbastelle (*Barbastella barbastellus*), Eurasian lynx (*Lynx lynx*), stoat (*Mustela erminea*) and European rabbit, (*Oryctolagus cuniculus*) are likely to lose partially their habitats in the regions of Debrecen by the end of the 21st century.

4. List of scientific publications related to the PhD thesis

Publications

- Bartholy J., Pongrácz R., Nagy J., Pieczka I., Hufnagel L. (2012): Regional climate change impacts on wild animal's living territory in Central Europe. Applied Ecology and Environmental Research, 10(2), pp. 107-120.
- Nagy J., Bartholy J., Pongrácz R., Pieczka I., Breuer, H., Hufnagel L. (2015): Analysis of the impacts of global warming on European terrestrial wild bat species' range area in the 21st century using regional climate model simulation Időjárás, in press

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- Nagy J., Bartholy J., Pongrácz R., Pieczka I., Breuer H., Hufnagel L. (2012): A várható regionális klímaváltozás hatásának elemzése az Európában vadon élő szárazföldi emlősök élőhelyére ENSEMBLES szimulációk felhasználásával, HUNGEO, pp. 229-234. Eger, 23 August 2012
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- Nagy J., Bartholy J., Pongrácz R., Pieczka I., Breuer H., Hufnagel L. (2012): How the possible living territories of the European terrestrial wild vertebrates are projected to change due to the global warming? Bioclimate Conference, Bioclimatology of Ecosystems, Csehország, Usti nad Labem, ISBN: 978-80-213-2299-8 pp. 76-77. 2012. augusztus 29.-31.
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- Nagy J., Bartholy J., Pongrácz R., Pieczka I., Breuer H., Hufnagel L. (2013): Analysis of the impacts of global warming on European terrestrial wild mammals' range areas in the 21st century using ENSEMBLES climate simulations "Tudomány a fenntarthatóságért" PhD hallgatók nemzetközi konfernciája, Nyugat-magyarországi Egyetem, Győr 2013. március 19.-20.
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- Nagy J., Bartholy J., Pongrácz R., Pieczka I., Breuer H., Hufnagel L. (2013): How may the regional climate change redraw the European terrestrial wild mammals' living territory in the 21st century? Geophysical Research Abstracts, Vol. 15, 13796. European Geosciences Union General Assembly, Ausztria, Bécs 2013. április 8.-12.

Lectures

- MTA-TKI Alkalmazkodás a Klímaváltozáshoz Kutatócsoport, A klímaváltozás várható hatásának elemzése az európai vadon élő szárazföldi gerincesek élőhelyére az ENSEMBLES szimulációk felhasználásával 2100-ig, Budapest 2012., június 8.
- A XXI. században várható klímaváltozás hatása az Európában vadon élő szárazföldi gerincesek élőhelyére,"Légköri hatások az állatokra" Magyar Meteorológiai Társaság Éghajlati Szakosztálya és az Agro- és Biometeorológiai Szakosztálya által közösen rendezendő, OMSZ, Budapest, 2013. január 31.

Posters

- Nagy J., Bartholy J., Pongrácz R., Pieczka I., Hufnagel L. (2012): A klímaváltozás hatásai a Kárpát-medencében vadon élő szárazföldi gerincesek élőhelyére, ELTE Innovációs Nap, Budapest, 2012. február 12.
- Nagy J., Bartholy J., Pongrácz R., Pieczka I., Hufnagel L. (2013): Hogyan változik az Európában vadon élő szárazföldi emlősök élőhelye a klímaváltozás következtében a XXI. Század végére? ELTE Innovációs Nap, Budapest, 2013. február 26.